DARPA SenseIT Program
Collaborative Signal and Information Processing

Santa Fe, NM
January 16, 2002

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Presentation Overview

- Accomplishments
- Collaborative System Architecture
- Sensors and Signal Analysis
- Collaborative Processing
- On-Going Work

Accomplishments: March 2001

- **Successful demonstration at MCAGCC in 29 Palms**
  - **Target tracking over a wireless sensor network.**
  - **Position estimates used to trigger imager.**
- **Implementation on Sensoria WINS 1.0**
- **BAE robust multi-modal detection and Kalman tra**
- **Penn St. interface code and ISI Directed Diffusion**

Major Issues from March Demo

- Node Time and Node2Node Synchronization
- Filtered and Accurate GPS Positions
- Logging Errors, “Event” Messages, Heartbe
- Software Setup and Control Mechanisms

Sensor Agent Processing Software (SAPS)

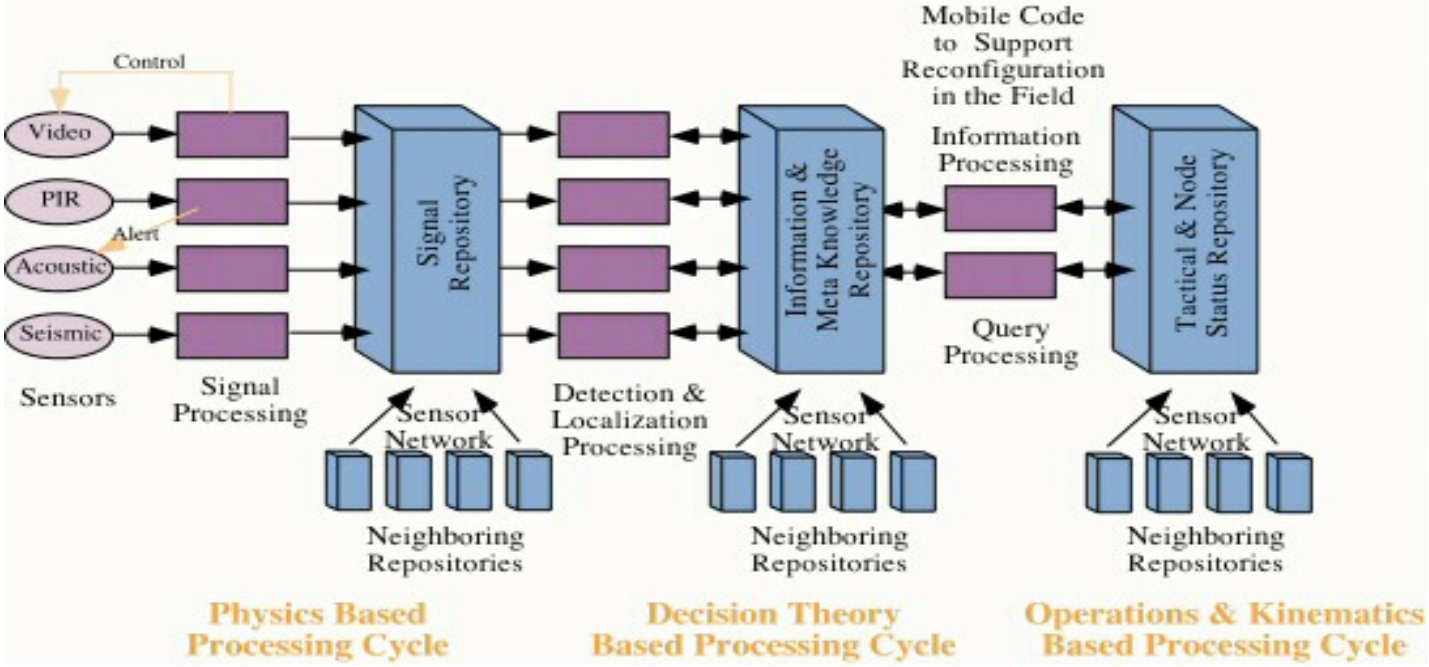
Accomplishments: April-Nov. 200

- Translated code from WINS1.0 to WINS2.0 (WinCE on MIPSR4000 to Linux on SH4) .
- Low level processing, improved repositories, APIs
- Robust adaptive detection on three sensing moda
- Kalman tracker.
- Sensor tests and calibration experiments.
- Radio and multi-node timing tests.
- Integration and test procedures for CSIP.
- Participated in both Operational and Developmen experiments at MCAGCC in 29 Palms, CA.

Collaborative System Architecture

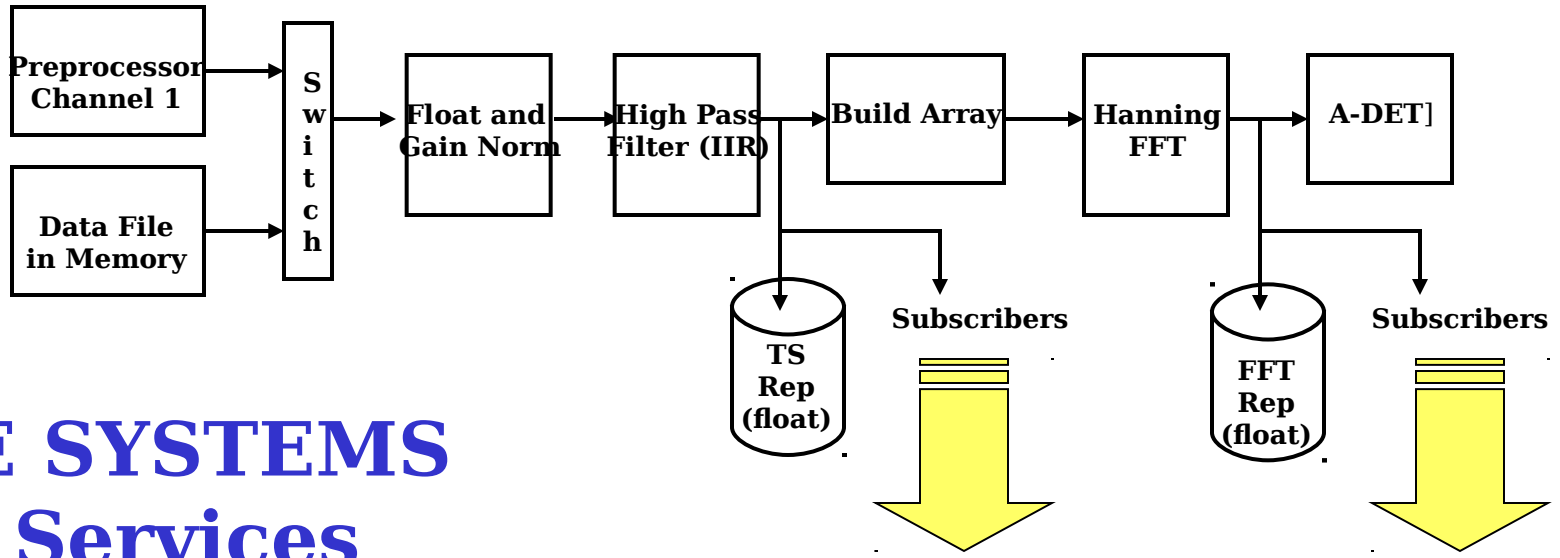
Node Software Architecture

- **Robust adaptive multi-modal sensor data proc**
- **Five repositories to support collaboration, dyn**
  situation awareness, and decentralized data fu



Sensor Agent Processing Software (SAPS)

Low Level Acoustic Processing



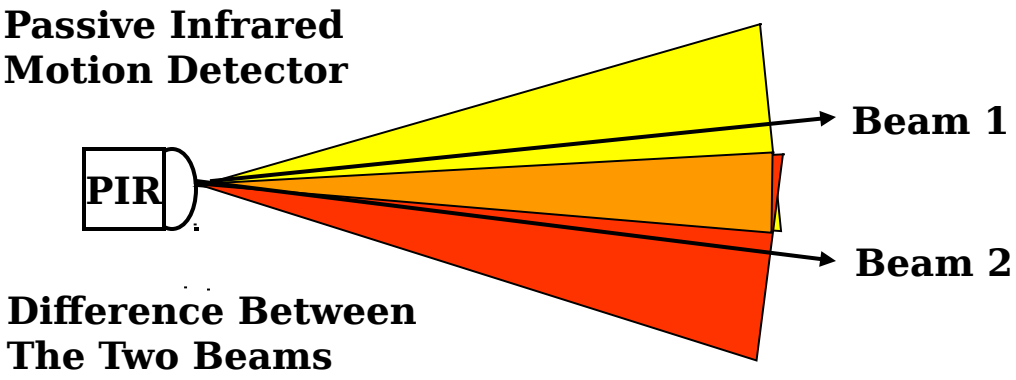
BAE SYSTEMS API Services

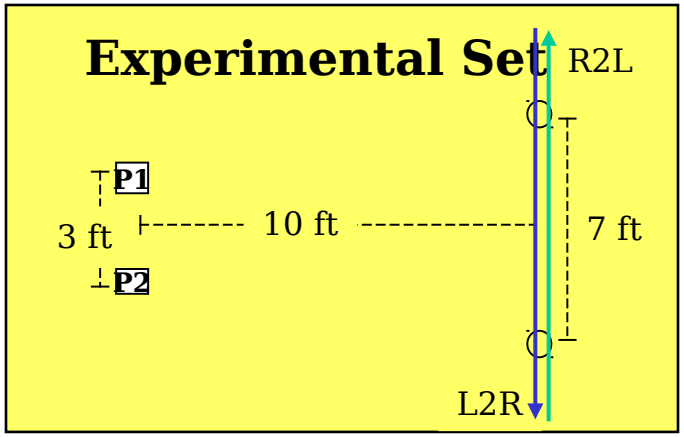
Plug and Play

Publish and Subscribe Mechanism
Data and Information Repositories
Consistent with Directed Diffusion

Sensors and Signal Analysis

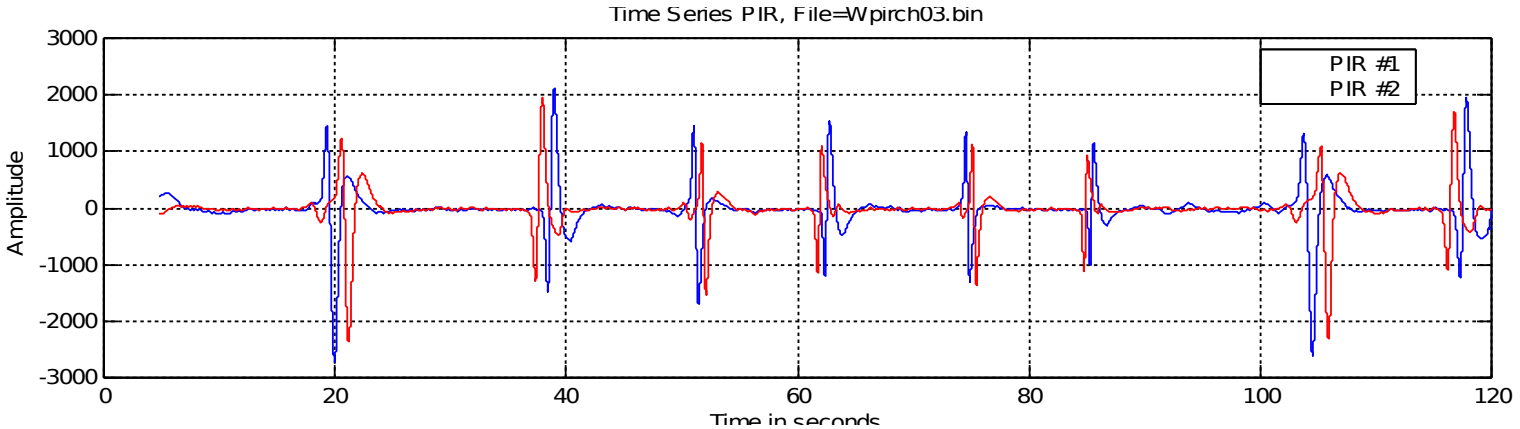
Signal Analysis: PIR Sensor





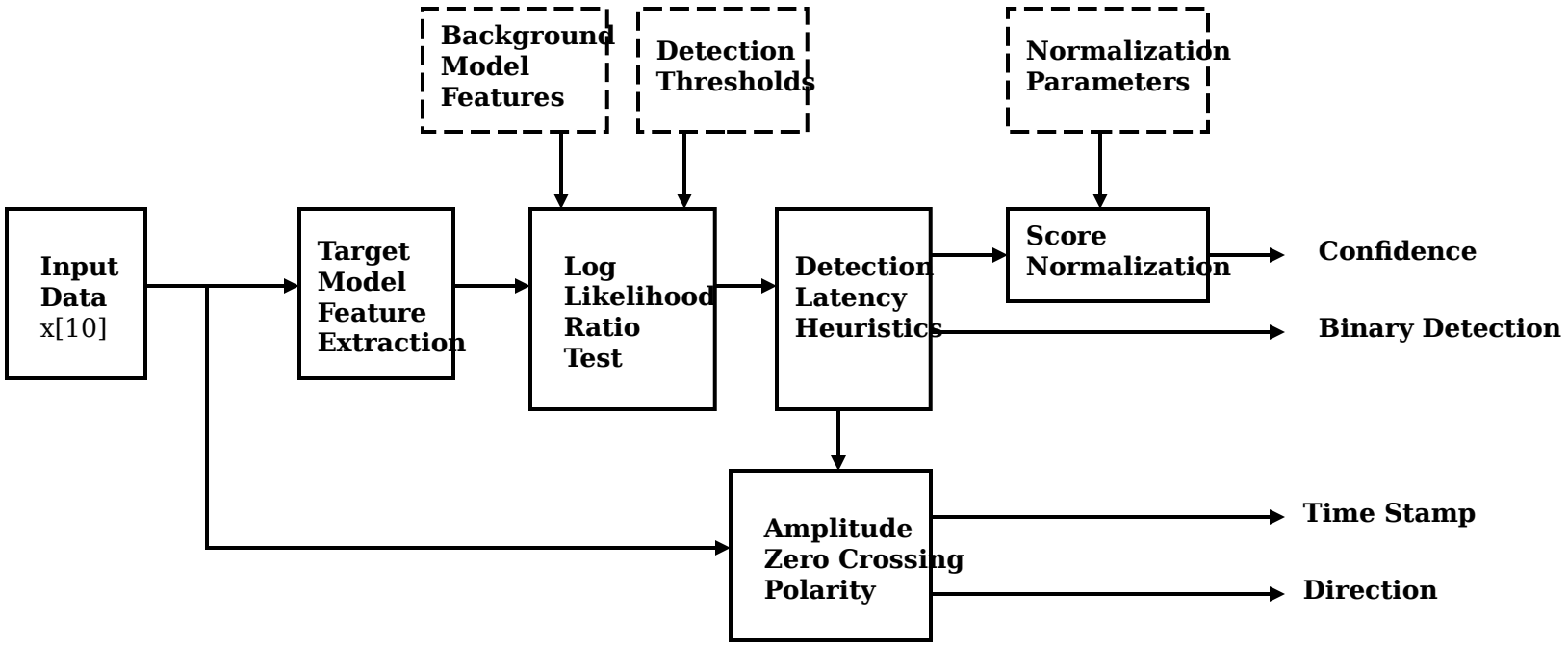
Time Series Record

Data File = matlab/wbk/pir_exp/wpirch03.bin
Display Program = matlab/wbk/pir_exp/viewpir



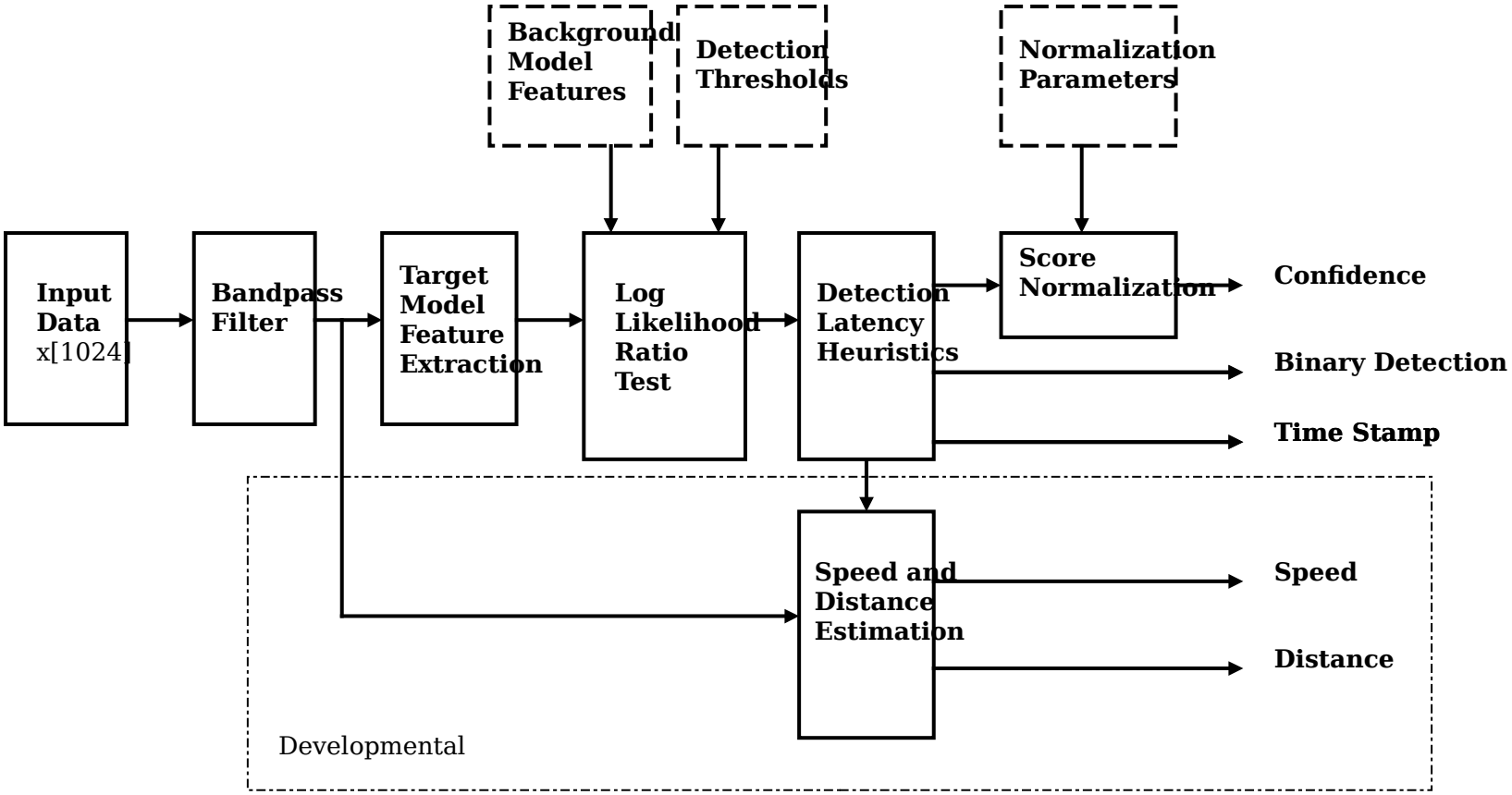
L2R = Right to Left	L2R	R2L	L2R	R2L	L2R	R2L	L2R	R2L
R2L = Right to Left	2.4 ft/sec	2.8 ft/sec	4.5 ft/sec	4.9 ft/sec	5.6 ft/sec	5.7 ft/sec	2.1 ft/sec	2.8 ft/sec

PIR Detection Processing



Sensor Agent Processing Software (SAPS)

Acoustic and Seismic



Sensor Agent Processing Software (SAPS)

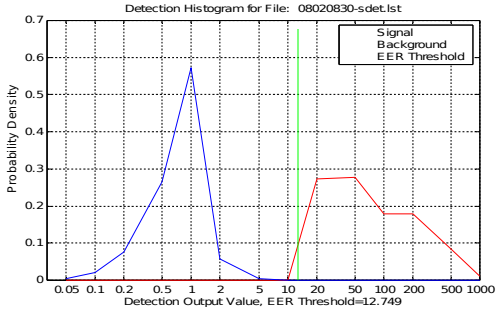
Detection for Multi-Modal Sensors

Legend

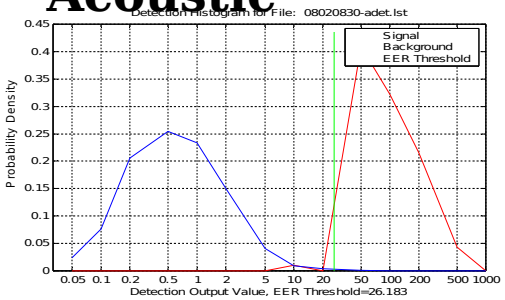
- Background
- Target
- EER Point

Robust Likelihood Ratio Test Detection

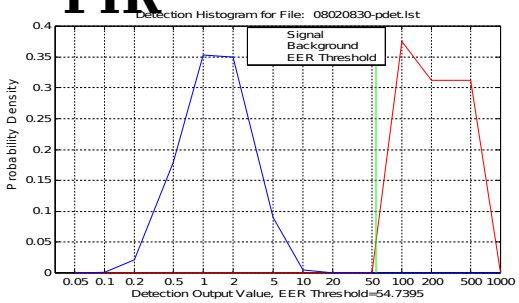
Seismic



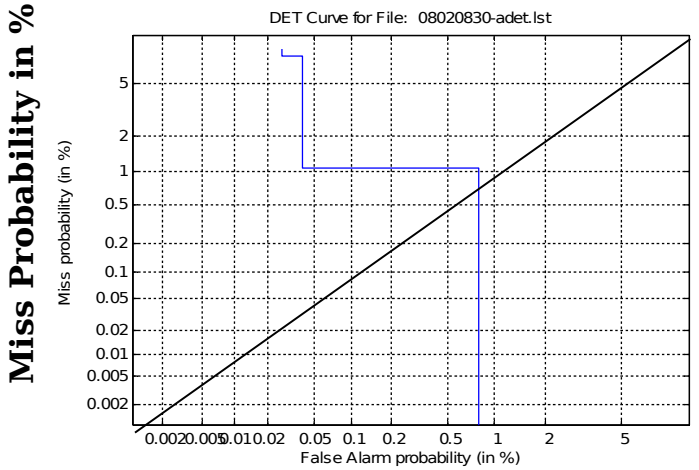
Acoustic



PIR



Acoustic DET Curve



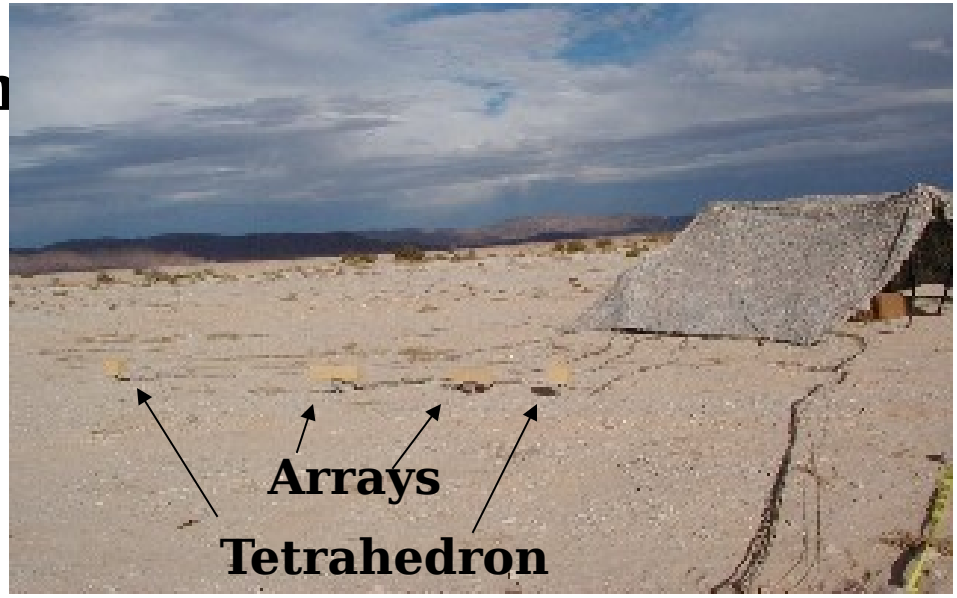
False Alarm Probability in %

For SITEX00 data from August 2
Acoustic EER = .008 per 0.5 sec
Seismic and PIR EER < 10^{-5}.
Combined sensor detection EER

Complementary Sensing Capabilities

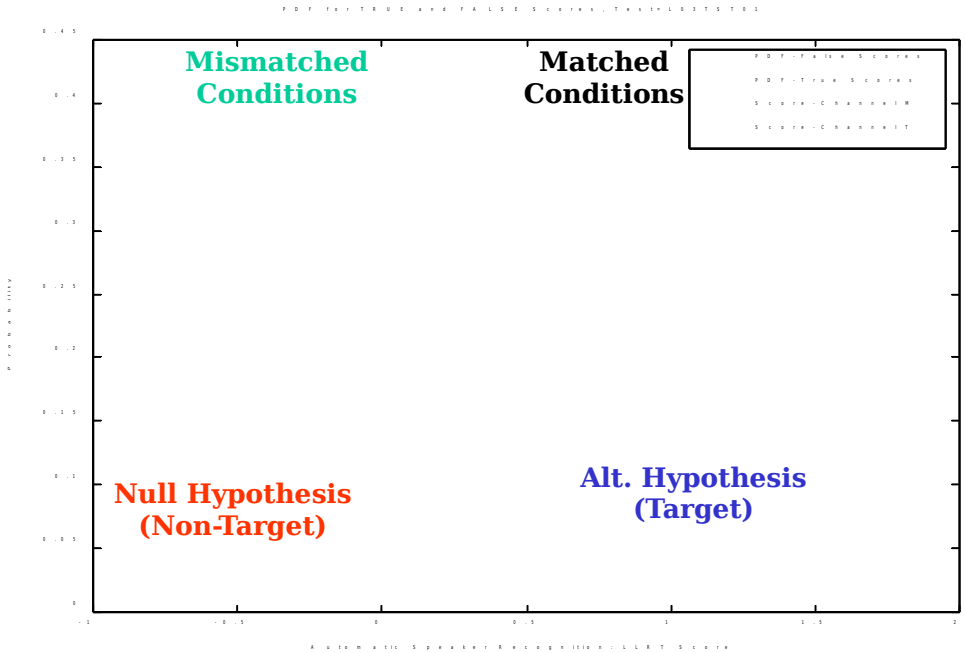
29 Palms Data Collec

- Acoustic and Acoustic
- Seismic and 3-Axis Se
- PIR
- Accelerometer with m ground couplings
- Micro Radar
- Magnetometer



Bayesian Conditional Normalizati

- **Adaptive to target and environmental priors**
- **Outputs confidence levels conditioned on expectations**
- **Empirically sound results - used in forensics.**



The black line = score with the SAME operating conditions as the training s
The green line = score from MISMATCHED operating conditions as the trai

Collaborative Signal and Information Processing

Target Signal Classification

Simple Entropy Classifier - SITEX00

Renya α-entropy discriminant function
Computational, memory requirements = low
Not effective for dynamic or multi-modal signals
Classifier design - data intensive

Matching Pursuits - SITEX01/BAE2002

PIR/Magnetometer discriminant function
Computational, memory requirements = medium
Efective for dynamic or multi-modal

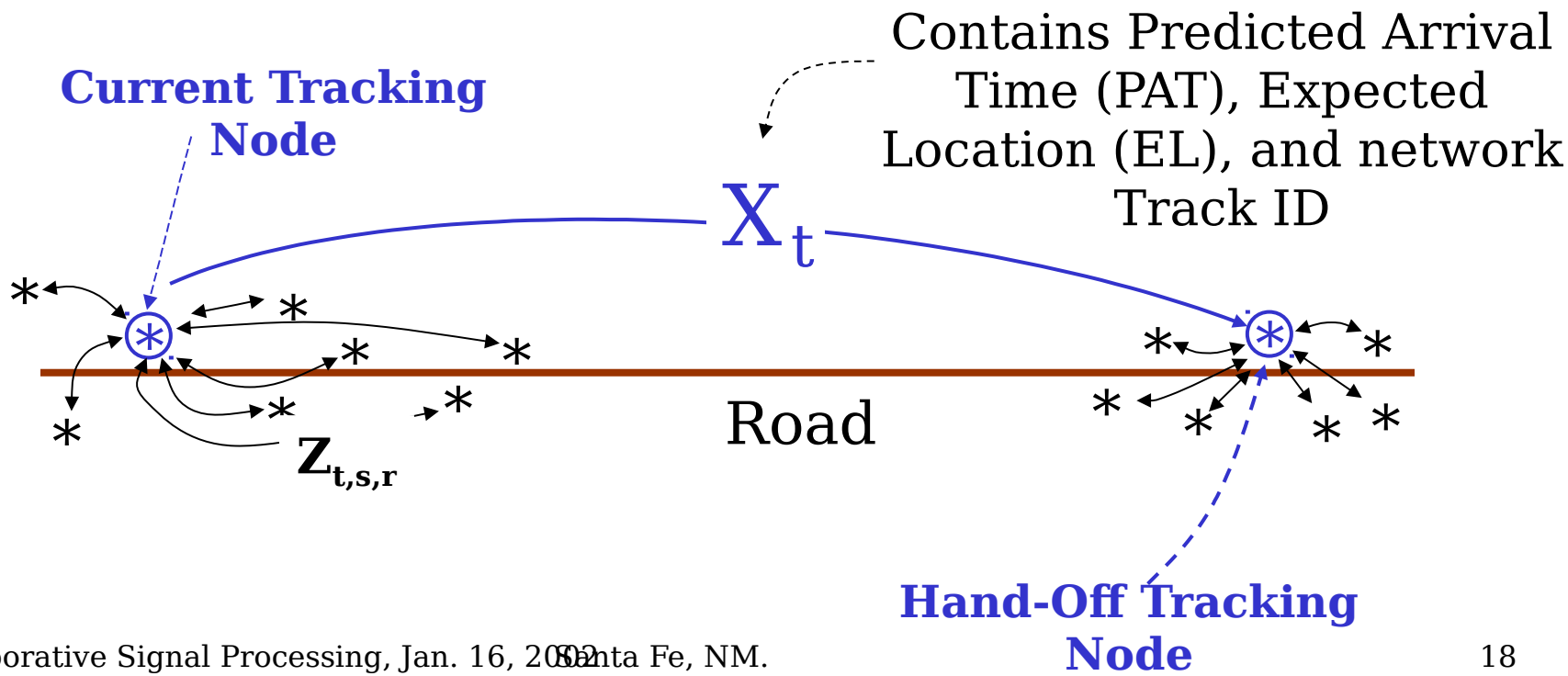
Rational Agent Classifier - BAE2001-2

Dynamic Bayesian belief networks
Computational, memory requirements = low
Effective for dynamic or multi-modal signals
Classifier design - qualitative description sufficient

n - Families of Basis

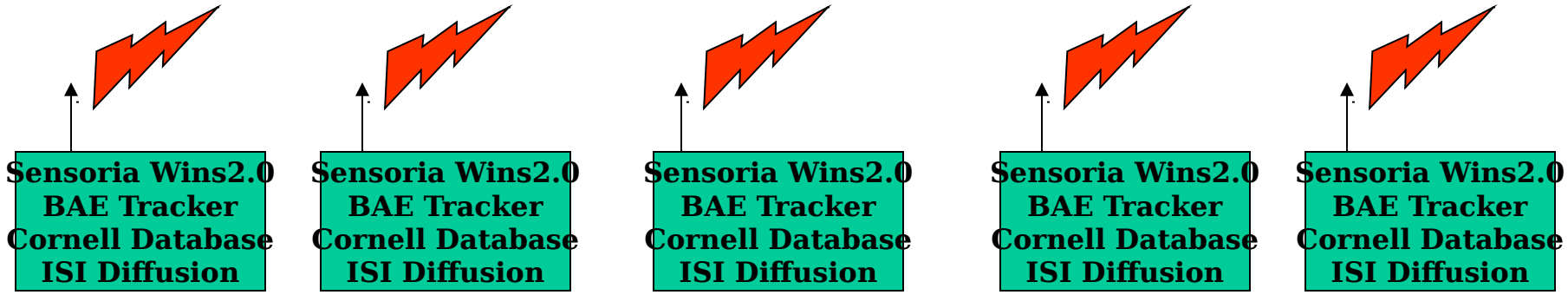
Decentralized Trackers

- **Kalman Tracker**
- **Probabilistic Multiple Hypothesis Tracker**
- **Decentralized Information Tracker**



Tracking System

Diffusion over Sensoria Radio



Team Members: Responsibilities

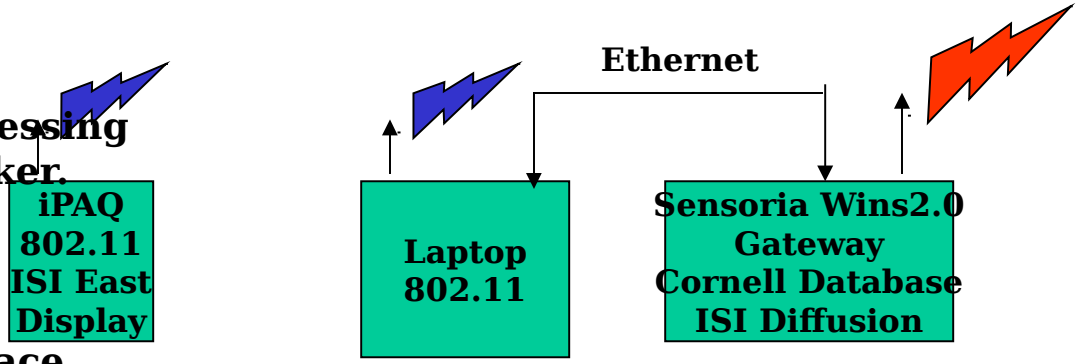
Sensoria: Wins2.0 hardware, radio.

BAE Austin: Multi-modal signal processing detection, and Kalman tracker.

Cornell: Distributed database query.

ISI West: Directed diffusion

ISI East: Grass display, 802.11 interface.



Sensor Agent Processing Software (SAPS)

Working in the Santa Fe hotel room preparing for the real-time wireless dem

Scientific Team for Operational Multi-Processors

Carl, Brian, Johannes, Joe, Jorgen, and Man
Not shown are Steve (taking the pic) and Fa

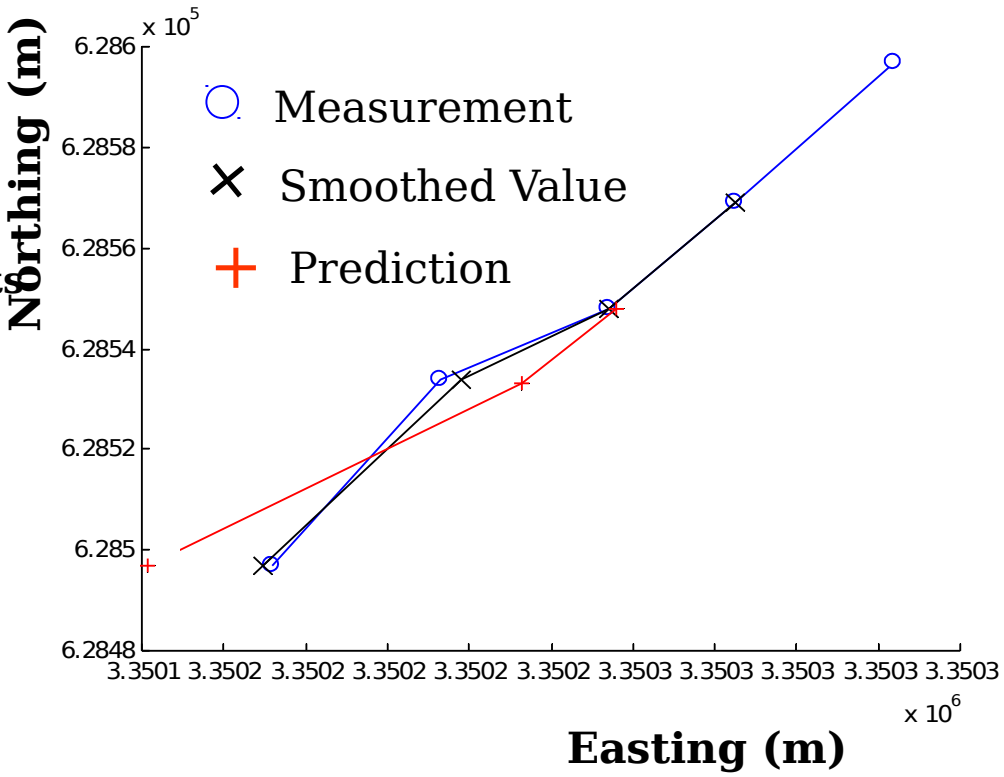
Tracking Results

Target Moving Southwest

January 13, 2002
Austin Test Site
Lake Road

Real-time Kalman Tracker Results
Southwest Vehicle Runs

Kalman	Trial 1	Trial 2
GT Speed	15 mph	15 mph
Node 35	18	18
Node 36	18	17
Node 37	18	18
Node 38	11	11



Errors primarily due to GPS node position errors, and driver speed errors.

DDF Information Tracker Results

Tracking Results

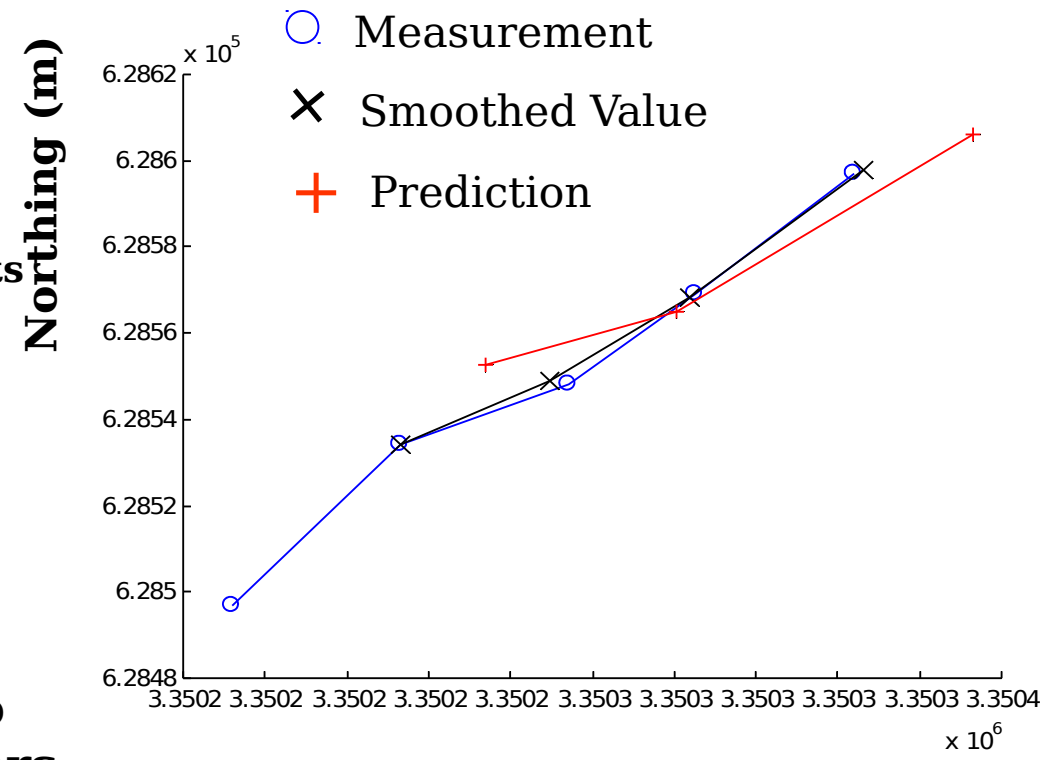
January 13, 2002
Austin Test Site
Lake Road

Real-time Kalman Tracker Results
Northeast Vehicle Runs

Kalman	Trial 1	Trial 2
GT Speed	15 mph	15 mph
Node 37	13	13
Node 36	20	23
Node 35	17	12
Node 34	18	18

Errors primarily due to GPS node position errors, and driver speed errors.

Target Moving Northeast



DDF Information Tracker Results

Information Filter*

- Maintains the same information as a Kalman filter, but in inverse covariance form
- Update in response to new information is much simpler
  - $Y(k+1|k+1) = Y(k+1|k)+I(k+1)$
  - $\hat{y}(k+1|k+1) = \hat{y}(k+1|k) + i(k+1)$
- Prediction and state estimation are more complicated
- In distributed data fusion with many nodes, information update is needed much more often than prediction or state estimation

*Decentralized Data Fusion
Prof Hugh Durrant-Whyte
University of Sydney, Australia

On-Going CSIP Development and Testing

Sensor Agent Processing Software (SAPS)

API Services for Distributed Sensor Networks

Operational Functionality and Support

- Low level signal processing.
- Repositories for TS, SP, and HL data and information.
- Robust adaptive detection for multi-modal sensors.
- Decentralized Kalman tracker.
- Simple target classifier.
- Event logging and post analysis

Developmental Functionality and Support

- Bayesian conditional processing.
- Power Aware detection, Rational agent classifier.
- Localization using array bearing estimation.
- PMHT and DIF tracking.
- Tactical query decision support.

Intelligent Surveillance and Reconnaissan

Tactical Situation Awareness

BAE Field Test and Demonstration S

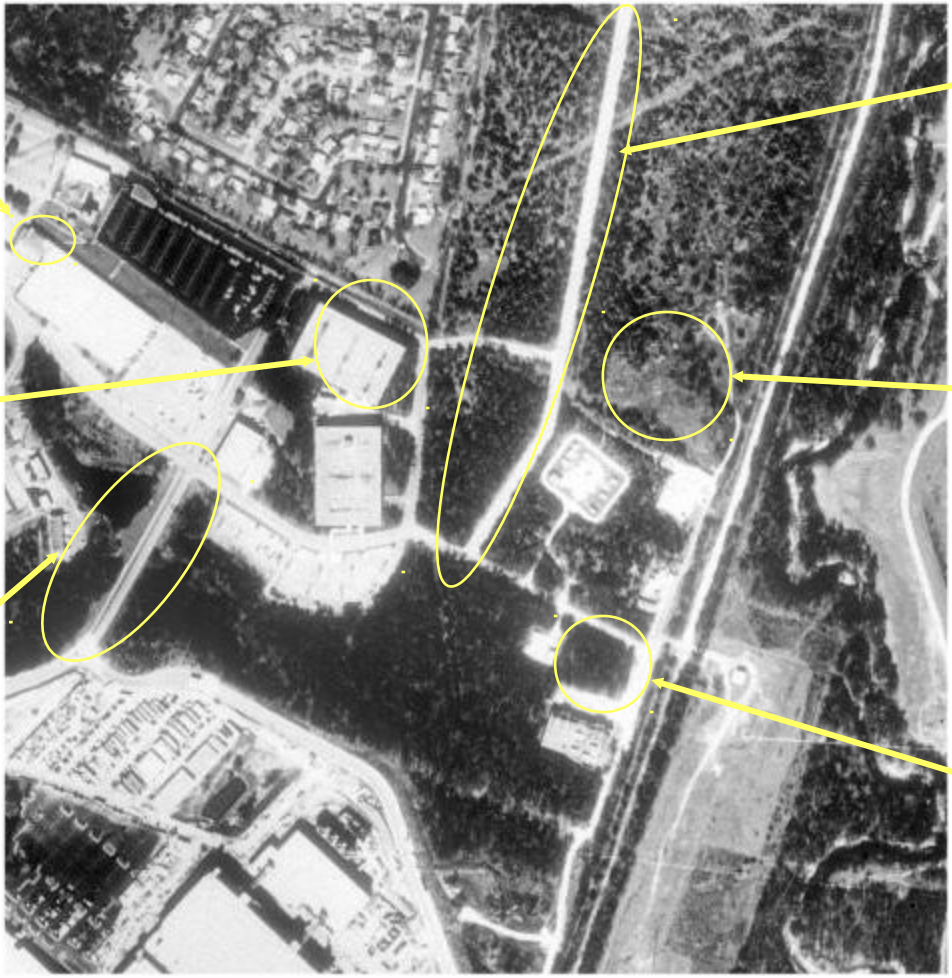
BAE Austin is starting a series of sensing and tracking exercises. These are targeted at situations not encountered at 29 Palms. They will force evaluation of sensors, algorithms, and systems.

Addresses many of Jim Reich's Challenge Problems

- Tracking Environment / Scenarios
  - Unconstrained
  - Intersection
  - Linear
- Field Configuration
  - Sensing Distance
  - Node Placement
  - Path Options

- Sensing Environment
  - Grassland
  - Tree Cover
  - Roadway
  - Building Proximity
  - Building Interior
- Radio & GPS Environment
  - Grassland
  - Tree Cover
  - Roadway
  - Building Proximity
  - Building Interior

BAE Austin Field Test Site - Aerial



Building Alcove
- Flexible Approach
- Low Buildings
- People and Vehicles

Hallways
- Interior Environment
- Limited Exposure
- People

Open Roadway
- Linear Approach
- Intersection
- Open Environment
- Quiet Seismic

Long Roadway
- Extended Tracking Time
- Intersection
- Tree Line / Open Margin

Test Field
- Unconstrained Approach
- Flexible Lay-down
- Grassland
- Brush

Tree grove
- Flexible Placement
- Flexible Approach
- Pavement and Grass Surface

Node Setup Along the Road